Resilient Urban Mobility
A Case Study of Integrated Transport in Ho Chi Minh City
A research project carried out by Arup and Siemens
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Population growth, urbanization and intensifying weather-related hazards are putting modern cities under increasing pressure to support and protect their inhabitants and infrastructure.

Future cities will need to be more robust and coordinated to manage the everyday stresses and intermittent shocks they face. By building resilience into the design of urban infrastructure systems and into their investment appraisals, cities and their citizens will be better able to manage these stresses and shocks in the face of a complex, uncertain and ever-changing future.

Transport systems are among the most complex and critical systems of a large city. They are essential to the day-to-day running of cities, as well as their longer term growth and prosperity. At the same time they are also at risk from a variety of shocks including flooding, heat waves, earthquakes as well as chronic or recurring stresses such as traffic congestion and accidents. Cities must increasingly adapt, expand and reinforce their transport systems to withstand such changes. Technology and in particular ‘smart’ and integrated systems provide ways to minimize risks and enhance resilience in cities.

Resilience and vulnerabilities occur and interact across multiple systems and multiple scales; this means that timely, good quality data about the conditions and performance of these across the systems is a critical characteristic of a resilient city. In the context of the transport sector, information and communications technologies can provide a powerful platform for integration of systems and modes to achieve flexibility, redundancy and responsiveness – some of the essential qualities of resilience. A resilient, integrated system will in turn provide users with a seamless, reliable, efficient multimodal service.

This report focuses on the use of technology solutions to enhance the performance, integration and resilience of transport systems, particularly in rapidly growing economies at risk from weather-related hazards. It employs a case study of Ho Chi Minh City and an economic appraisal of a range to transport technologies to illustrate the value and benefits these technologies could bring to cities like Ho Chi Minh.

The report was prepared jointly by Siemens and Arup, drawing on a combination of our real-world project experience, published data and literature, and discussions with transport and city experts from around the world. The Ho Chi Minh case study drew on published data at city and national scale and on interviews held with a range of government and non-government actors within the city. We wish to express our gratitude for the time all of our interviewees gave us and the insights they provided.

Gregory Hodkinson
Arup Group Chairman

Dr. Roland Busch
Member of the Managing Board of Siemens AG
Executive Summary

Transport is linked to all aspects of urban life: leisure, education and business. Ensuring a comprehensive, accessible and integrated transportation system is essential to sustain social and economic development. The central role of transport networks in urban life means that any reduction in performance may compromise the city’s operations across a number of sectors, causing large and costly disruptions. A resilient system is essential to avoid such events. Recent evidence suggests that the frequency, extent and severity of extreme weather events is increasing around the world, exposing transport infrastructure to more severe stresses and sudden (shock) events. Anticipating and preparing for impacts of these stresses and shocks on the transportation systems is key to achieving and sustaining resilient urban mobility.

**Increased Demand for Transportation Services**

Rising populations, especially in emerging city economies, imply densification and urban sprawl, trends which are already creating new demand for mobility as well as increasing pressure on existing urban transportation systems. Changing weather patterns will compound these challenges as the frequency and severity of damaging weather events increases over time. Cities will need more effective systems to forecast, respond to and recover from these events to ensure that periods of disruption are minimised and long-term economic sustainability is not undermined. In Ho Chi Minh City, for example, the number of delay minutes is forecast to increase by 620% over the next 30 years.

**Integrated Transportation Solutions**

Management practices and software-based solutions that make better use of capital intensive infrastructure and generate reliable revenue streams will be necessary to address the transportation challenge.

Integrated systems offer greater flexibility, coordination and redundancy, allowing users to be distributed across a diverse portfolio of transport options and to transfer easily from one mode to another when required. Better integrated systems provide a smoother, more efficient and user-friendly day-to-day service which is also better able to cope with the stresses associated with peak demand and strains of infrequent shocks or unforeseen events. The Ho Chi Minh City case study included in this report demonstrates that the net benefits the city can expect by investing in a selection of intelligent transportation technologies exceeds $1.6 billion and clearly justifies the investment. The economic appraisal to support this study suggests that the proposed solutions offer excellent value for money, with the city receiving $3.30 in economic benefit for every $1 invested. This report showcases a number of technologies currently deployed globally that – by generating, processing, analysing and distributing data – can improve the efficiency, capacity and flexibility of transportation systems.
Case Study: Ho Chi Minh City

Ho Chi Minh City (HCMC) is witnessing a dynamic phase of economic growth, industrial expansion and land use change which is raising the city’s fortunes and attracting business opportunities. However, at such a rapid pace of transformation, the city is also facing a host of challenges from lack of housing and inadequate infrastructure, to poor air quality and rising transport congestion.

HCMC’s traffic congestion is estimated to have a direct cost to the economy of approximately $97 billion between 2015 and 2045. Around 45% of HCMC is less than a meter above sea level, rendering the city and in particular, the transport system highly exposed to flooding, especially during the rainy season. Regular flooding in parts of the network compounds the challenges of congestion by reducing the total capacity of the network and diverting traffic on to alternative routes. Routine upgrades and new investments in HCMC’s transportation system represent a unique opportunity to improve resilience on all of the city’s future services and create a more inclusive environment in which economic and social demands can be met. In short, the resilience of the network and, in turn, the city can be improved.

A first step to increase resilience could be to establish an integrated traffic control center and associated street-based technologies, which incorporate the infrastructure and equipment required to effectively manage traffic flows and the city’s transport system remotely and in real-time. In addition, an Inter-operator Fare Collection (IFC) solution that functions across public transport modes may reduce delay time resulting from passenger payments, while also making it easier for passengers to access multiple modes. This would stimulate mode shift away from private vehicles and contribute to increasing resilience by providing flexibility, redundancy and an alternative means of travel to the motorcycle or car.
Economic Benefits of Investing in Technology

An economic appraisal was undertaken to demonstrate the business case for investing in transport technologies. The appraisal demonstrates that these would bring enormous benefits to a city like HCMC, not only to road users in terms of reduced delays and improved air quality, but also through the wider economic benefits that result from a well-functioning transport system.

The analysis indicates that an Integrated Traffic Management System (ITMS) would take only eight years to become net positive in terms of costs and benefits and represent a net benefit of $1.4 billion over the next 30 years. Based on the forecast number of trips on the transport system, an Inter-operator Fare Collection (IFC) system is expected to generate a total net benefit of $0.2 billion.

Economic analysis of the annual discounted costs and benefits for a combined ITMS and IFC solution, 2015 and 2045
Accessing Finance for Infrastructure Improvements

Despite the clear benefits of investing in transportation technologies, access to finance is often the major barrier for investments in infrastructure. Ideally, funding would be drawn from transport revenues in order to ensure that the beneficiaries of the systems were the same groups that contribute to their funding (i.e. the ‘user pays’ principle). For example, an increase in fuel duty of $0.03 per liter (around 1.75% of current fuel prices) could lead to initial revenues of $145 million in 2015, generating revenue of $3.4 billion over the 2015-45 period. This revenue stream alone would adequately fund both an Integrated Traffic Management System and Inter-operator Fare Collection.

Revenues from these sources may be used by cities either to finance a project in its entirety, or to seed fund new initiatives and open up opportunities to access funding from development bank loans or private finance mechanisms, among other sources.

How to Make it Happen

In addition to finance, a series of other enabling actions are required to support the implementation of transport technology solutions in cities. An enabling framework for HCMC would include effective cooperation between stakeholders at various levels of city administration, ensuring the development and delivery of an integrated multi-modal transport plan. This may require the implementation of updated policies to guide the development of urban planning, the evolution of new bodies to coordinate cross-sector activities, the training of staff to operate new equipment and analyse the output data and trends, and the pursuit of new approaches to secure alternative sources of financing.

The results from this report are not unique to Ho Chi Minh City and may be applicable within the context of any city, regardless of infrastructure age or scale of operation. They are particularly pertinent, however, to cities like HCMC that are facing significant weather related risks and severe road traffic congestion. For these cities, technology solutions and an integrated framework for their implementation would help not only to improve the functionality and efficiency of the future system, but also to enhance the characteristics of resilience by creating redundancy, responsiveness, coordination and flexibility.
In 2013, Siemens and Arup partnered with the Regional Plan Association of New York, New Jersey and Connecticut (RPA) to prepare the Toolkit for Resilient Cities: Infrastructure, technology and urban planning. The report recognised the growing frequency, magnitude and extent of weather-related disasters around the world, and particularly in cities, where a growing proportion of the world’s population resides. We explored the concept of ‘resilience’ as a means to ensure that cities can survive and thrive in the face of acute shocks and everyday chronic stresses, focusing particularly on the role of technology in reducing risks to infrastructure systems. Through a case study of the electricity supply network in New York City – which was severely affected by Superstorm Sandy in 2012 – we demonstrated the benefits available from investment in technologies that foster system resilience.

This report draws on the Toolkit to consider in more detail the delivery of resilience in relation to urban transportation systems. We have focused on transportation systems as they underpin the daily economic and social fabric of cities and provide an essential lifeline during an emergency. In addition, transport in a large city is a system of tremendous complexity, which makes it a particularly appropriate candidate for the application of technologies to help managers and citizens to operate and use the system effectively in the face of shocks and stresses.

Technology can increase the flexibility of infrastructure and provide benefits for transport providers and users on a daily basis by increasing the capacity, reliability and flexibility of services. These outcomes are often enabled by tools that gather and process data from infrastructure. Such tools can be operated remotely, helping to ensure that vital assets such as hospitals continue to function in spite of shocks and stresses.

In this study we evaluate potential technology solutions against the Toolkit’s characteristics of resilient systems. Furthermore, we identify some of the enabling actions required by policy makers, service providers and other city stakeholders to facilitate delivery of more resilient transport systems.

Our research is illustrated by a case study of the transport network in Ho Chi Minh City (HCMC), Vietnam. As a rapidly growing delta city with a population of almost ten million, Ho Chi Minh City faces significant risks from weather-related shock events such as typhoons and storm surges, as well as intensifying stresses from urbanisation, population growth and economic variability. The city’s transport network is also set to undergo a dramatic transformation through planned investments of over $50 billion in rail and road infrastructure over the next 15-25 years.

This study uses an economic cost-benefit appraisal to illustrate the benefits of implementing advanced transport technology solutions in a growing city like HCMC. It examines how the integration of these technologies could enhance resilience and create benefits including journey time savings, air quality and road safety improvements, as well as gains in economic productivity. We use resilience as the goal to address the many challenges facing growing cities, whether as a result of natural or man-made factors. The specific focus of our work is the challenge of weather related hazards occurring against a background of rapid demographics and economic change.
Resilience as a Response to Uncertainty

Responding to weather related hazards involves decision making in a period of transition, in which there is continuing uncertainty about the severity and timing of climate change as well as the vulnerability, exposure and responses of interlinked human and natural systems. This uncertainty represents a major risk to cities. It may lead either to indecision and inertia in government policy, design and operational decisions, or to poor decisions and maladaptation. Although the costs of sound preparation and investment in resilience can be significant, without these investments the impacts of severe events will be far greater.

Resilience is a constructive response to a changing and uncertain future. A resilience approach employs proactive strategies and solutions to reduce risk across the full spectrum of potential risk areas, from climate change, to corruption, to civil unrest, disease pandemic or economic decline. A resilience approach enables a city to prepare for expected events and respond effectively to unexpected events, creating a capacity to survive and thrive in the face of uncertainty.

Extreme weather and man-made hazards interact with other shocks and stresses to significantly alter existing levels of vulnerability. Increased vulnerability is a particular feature of urban areas, many of which are confronting multiple hazards combined with stresses from rapid growth, economic turbulence and aging or inadequate infrastructure. For urban communities it is often the damage to infrastructure and settlements and the disruption of supply chains which, indirectly, have more severe consequences for human well-being and livelihoods than the direct impacts of severe weather. Weather events carry direct costs of response and recovery, but also trigger indirect costs through temporary disruption of travel, trade and economic growth.

The integrated nature of resilience means that, for a city to be truly resilient, it must be understood as a holistic system in which sub-systems like energy supply, transport, water distribution and waste removal – in addition to the social and economic networks that surround them – are highly interdependent. In the city, strengths and weaknesses in one sub-system may cascade into other sub-systems. Resilience must be a core objective for planning, design, management and operation in all aspects of the city.
Characteristics of Resilience

In our previous research, we identified five key characteristics of infrastructure systems that contribute to their overall resilience. The characteristics were used to assess a variety of technology interventions for urban infrastructure, to identify those that help to strengthen one or more dimensions of resilience.

Resilient transport systems possess all of these characteristics, from integrated multi-modal systems to real-time passenger and driver information systems. Resilient transport systems utilise data flows at every level; increasing the depth of information available to draw on, thereby increasing the efficiency and performance of each system. Effective use of data can enable a transport system to exhibit resilience characteristics. In a robust system, for example, historic and real-time data is collected and analysed to allow operators to forecast and mitigate potential problems. Similarly, a responsive system is supported by an ongoing exchange of data via interconnected channels that allow users to make informed decisions and operators to mitigate the damaging knock-on effects of failure in one part of a system.

From global positioning technologies used to monitor travel demand to the software and servers used to aggregate and analyses real-time information in traffic control centers, data is a critical ingredient of a resilient transport system. In the next chapter we examine urban transport systems through the lens of resilience in greater detail.

Robustness Robust systems are well-conceived, constructed and managed, so that they can withstand the impacts of hazard events without significant damage or loss of function. Robust design anticipates potential failures in systems, making provision to ensure failure is predictable, safe, and not disproportionate to the cause.

Redundancy Redundant systems have spare or latent capacity, which is purposefully created within systems so that they can accommodate disruption, extreme pressures, or surges in demand. Diversity in systems and resource supplies contributes to redundancy by providing alternative routes to fulfill a given function.

Flexibility Flexibility implies that systems can change, evolve and adapt in response to changing circumstances. This may favor the use of distributed, modular and/or decentralised resources, multifunctional equipment, and appropriate use of new knowledge to change practices as needed.

Responsiveness Responsive infrastructure systems incorporate automated monitoring, short feedback loops and controls at multiple points, enabling transparency of performance data, encouraging system managers to reflect on and learn from past performance, and to modify operations based on emerging evidence.

Coordination Coordination between systems recognises the intrinsic interdependencies in the way city systems work. Coordination promotes alignment and consistency in decision making and management, to ensure that all actions are mutually supportive towards a shared outcome.
Mobility in the resilient city

It takes only one major storm to demonstrate the importance of a resilient transport system to a city. Redundancy is needed to accommodate evacuations or diversions from affected parts of the city. Flexibility and diversity will facilitate emergency services and aid teams to reach affected communities. Robust infrastructure limits damage to enable businesses, government and civil society to maintain critical functions and quickly restore business-as-usual. Without these qualities of resilience, mobility can be severely undermined, leading to a breakdown in many other systems and hindering both preparation and recovery from a shock event.

But mobility is also critical to normal, day-to-day life in cities. The ability to travel enables citizens to access essential services, maintain livelihoods and participate in communities. Beyond its value to individuals, mobility supports commercial networks by facilitating trade and business relationships both within the city and across a wider region. The presence of a well-designed, well-functioning transportation system is a key factor for attracting and retaining businesses and residents in cities and, consequently, for cities’ long term prosperity.

In this chapter we briefly identify the components of urban transportation in terms of infrastructures, users and operational structures, and highlight the spectrum of shocks and stresses with which a resilient transport system must cope.

Components of urban transportation

Transportation systems are perhaps the most complex of all systems to be found in major cities. In most cities there is a mix of intersecting infrastructures and transport modes and a mix of competing and overlapping private and public system operators. Furthermore, unlike other network infrastructures it is people that are being carried around the network. Therefore the design and performance of the transport system must address matters of safety, comfort and convenience, and flexibility as well as the more typical infrastructure performance indicators of efficiency, responsiveness, connectivity and reliability.

Although roads and rail-tracks form the basic infrastructure, their effective use relies upon an overlay of monitoring, management and communication, from simple street signs and traffic lights to highly complex traffic flow sensors, GPS-based fleet management software and integrated transport control centers. The nature and functionality of these systems and technologies are discussed in more detail in Chapter 3.
Transportation and the demand for mobility place some major stresses on cities. Simultaneously, they are highly exposed to sudden shocks. Linear routes crossing the city can be easily disrupted, blocked or damaged by severe storms, flooding, overheating or other major events. If transportation networks are compromised, the city may be brought to a halt as people cannot reach work; food and other deliveries fail; and emergency or support services are hindered. Risks to the transportation network therefore indirectly threaten the entire city system, with cascading impacts for the domestic and international economy.

Compounding challenges

The world is urbanising at an unprecedented rate, with more than half of the global population currently living in towns and cities. By 2025, the number of city dwellers may reach 4.6 billion people; around 70% of the global population. The majority of growth will be concentrated in smaller towns and cities, especially in Asia. Rising populations imply densification and spread of urban areas, a trend which is already bringing growing demand for mobility and increasing challenges for urban transportation systems.

As highlighted in the previous chapter, climate change will also compound the challenge to transportation systems as the frequency and severity of damaging weather events increases over time. Cities will need more effective systems to forecast, respond to and recover from these events to ensure that periods of disruption are minimised and their long-term economic sustainability is not undermined by damage to infrastructure.

In fast growing cities, transport requires large and far-reaching investments in infrastructure and assets including rail, roads, airplanes, trains and ships. Future infrastructure planning must take into account climate change impacts as well as socio-economic changes likely to take place in the city.

In 2012, more than 3,000 deaths in the UK capital were attributed to exposure to vehicle emissions.

The cost of traffic congestion in London has been estimated at around $2,000 per household per year.
In October 2012, Superstorm Sandy forced a two day closure of the New York Stock Exchange, largely due to the shutting of roads, bridges and mass transit services which inhibited staff travel. The impact of this local event rippled outwards as market trading was delayed throughout the US and overseas.

The ZVV system in Zurich is an example of the successful integration of physical, policy and technology interventions. Operated and financed by a public body under the authority of the Canton of Zurich, this multi-modal system delivers a ‘one ticket for everything’ approach combining trams, boats, trains, buses and cable cars. Intelligent Transportation Systems (ITS) are integral to the functioning of the system, as is a governance structure that includes transport system operators, municipal authorities and the regional government.

System integration for greater resilience

A key factor influencing the performance of a transport system is the level of integration in the planning, design and operation of different components. More integrated systems offer greater flexibility, coordination and redundancy, allowing users to distribute across a diverse portfolio of transport options and to transfer easily from one mode to another. Integrated systems tend to provide a smoother, more efficient and user friendly service from day-to-day, while also being better capable of managing the stresses associated with peak demand and unusual events that affect capacity in parts of the system.

System integration is a product of physical, policy and technology interventions. For example, integration is visible in the way infrastructure is laid out and services are routed, such that multiple modes meet at key interchanges. From a policy perspective, integration may be facilitated by governing authorities that take a strategic approach across multiple modes and ensure appropriate regulation of local services and service providers.

The combined effects of rapidly rising demand for transport services and rising costs of impacts from both chronic stresses and periodic shocks will put a significant strain on the ability of cities to plan, fund, deliver and maintain the new infrastructure which will be needed to achieve and sustain resilient urban mobility. Management practices and software-based solutions which make better use of capital intensive infrastructure and generate reliable revenue streams will be particularly needed to address this challenge.
3 Increasing the Resilience of Transport Systems

Cities employ a variety of technology solutions to support integrated, flexible and robust transport systems that contribute to the resilience of the system itself, and in turn to the resilience of the city.

Individual transport technologies are increasingly being adopted by cities, whether simply to control traffic lights and monitor security, or to distribute live information to travelers and remotely manage operations. However, despite the increasing availability and decreasing cost of technologies, many cities – especially those that are growing most rapidly – fail to realise their full potential to foster overall system integration, improve efficiency, and enhance resilience.

**Robustness**

Sensors located on the transport network or embedded into infrastructure allow continuous monitoring of system performance and of the strength, stability and security of assets. This information can be used to inform the timing and content of operational interventions, maintenance regimes and renewals, helping to ensure long term robustness of the system.

**Redundancy**

Intelligent control technologies and real time information help to secure redundancy in transport networks, ensuring continued flows and preventing unwanted stoppages. By redirecting travelers away from congested routes or advising transit operators to bring more vehicles on to the network, technologies can help to create new capacity in the system.

**Flexibility**

In most major cities, transport networks are multi-modal and therefore inherently diverse. Even the most basic transport systems are likely to support pedestrians, bicycles, and cars or trucks of some variety. Technology can help to create greater integration between modes and improve travelers’ flexibility, for example by making cars or bicycles more accessible through public share schemes, or by enabling travelers to switch seamlessly between transit modes using a single ticketing facility.

**Responsiveness**

Technologies allow urban transport operators to have continuous visibility of the system, enabling them to respond quickly and appropriately to any disruption, whether by deploying emergency services, channeling information to travelers via internet, SMS or roadside displays, or by remotely controlling infrastructure operations to adjust performance in real-time.

**Coordination**

Information and communication technologies can improve coordination between transport managers to enable more joined-up decision making and strategic planning across modes. Greater coordination can improve the efficiency of system operations and help to maintain flows of people and goods.
Increase the Resilience of Transport Systems

Transport Technologies for Operational Efficiency and Resilience

For the purposes of this paper, we have categorised currently available transport technologies according to three overall purposes:

**Monitoring**

of traffic, travelers and infrastructure assets (data generation and processing).

**Management**

of traffic, travelers and infrastructure assets (data interpretation and action).

**Communication**

of traffic and travel information to transport operators and travelers (information distribution).

The following sections outline some of the relevant solutions under these three categories.
Monitoring devices enable transport managers to understand how the network is operating, including flows of traffic, passengers, asset conditions, and wider events that could affect system performance (e.g. weather or major events in the city).

Monitoring is widely promoted as a critical part of any management regime, since it generates the necessary information and understanding required for decision making and action.

As part of a city’s resilience planning, monitoring allows risks to be foreseen and mitigated to the extent possible, and residual conditions to be prepared for.

**Fixed sensor networks monitor traffic & environmental conditions around key transport infrastructure**

Radar technologies can be installed around critical transport junctions to count passing vehicles, identify stationary traffic, and detect cyclists, motorbikes and pedestrians. Inductive loop technologies, which are buried under the road pavement, are used for a similar purpose. Fixed sensors can collect data on travel speeds, vehicle types and the distance between vehicles, as well as weather conditions and pollution data. Improved information about vehicles allows greater signal control at intersections, which in turn helps to improve the flow of traffic in the city.

Radar has been used in the Sodra Lanken Tunnel, Sweden, to detect traffic incidents, and at junctions around London, UK, to detect stationary vehicles. On a smaller scale, micro radar technologies can also be used to manage parking spaces in cities by detecting when a space is occupied.
Remote asset monitoring enables responsiveness to sudden changes in service conditions or infrastructure functionality

In Kuala Lumpur, Malaysia, the integrated Storm water Management and Road Tunnel (SMART) has been designed to relieve the joint pressures of regular storm water flooding and severe traffic congestion around the city. The system diverts flood waters away from a flood-prone stretch of the Klang River via a holding pond, bypass tunnel and storage reservoir. A 4km long roadway is located inside the same tunnel, which can be closed to traffic to increase storm water retention capacity during major storms. The tunnel can be cleaned and reopened in as little as eight hours. SMART utilises a flood recognition system, which detects and forecasts rainfall and water levels upstream to assess when to close the tunnel; and a traffic management and control system which monitors and manages urban traffic in and around the tunnel. CCTV with Automatic Incident Detection technology monitors vehicle speeds and tunnel occupancy, while Supervisory Control and Data Acquisition (SCADA) systems gather and analyses real-time traffic data. Variable Message Signs (VMS) warn road users of forthcoming closures. Since opening, SMART has helped to improve travel times and increase resilience by providing robust and flexible infrastructure capacity. The Malaysian government estimates that the tunnel will prevent $1.6 billion in flood damages and save $1.3 billion in reduced traffic congestion during its 30 year concession period. A similar scheme is now proposed in Jakarta, Indonesia.

Anonymous mobile data positioning can be used to monitor travel demand and optimise service provision

Cellular monitoring uses real-time anonymised data from mobile cellular networks to monitor movements around the city, including transit ridership, congestion and incidents. Detecting potential problems on the transport network allows system operators to take appropriate action to rectify problems.

Cell based monitoring uses source location data from phone signals passing through individual cells on the network, thereby allowing individual data points and mass data streams to be tracked over space. Data can be used to model patterns of congestion and flows of people in the city, enabling real-time interventions while also informing future transport planning. In Abidjan, Côte D’Ivoire, mobile data has been used to re-route the bus lines in the city based on information about population movements.

Mobile data positioning has the advantage of requiring no additional fixed physical infrastructure; the necessary technology already exists in the cell network. As personal connectivity to mobile networks and applications grows, ‘floating data’ will become increasingly comprehensive and effective for city monitoring.
Increasing the Resilience of Transport Systems

Management tools are those that enable operators to act on the information they receive from monitoring devices, for example by allowing interventions for real-time allocation and reallocation of road space or dynamic road pricing based on demand. Management tools are inextricably linked with communication tools; the two are interdependent.

Technology allows systems to be managed in real time according to continuously changing conditions, offering advantages over static management programs in terms of optimised performance, greater efficiency, and an improved traveler experience of the system.

During disruption, such as traffic congestion, road accidents or closures, management tools enable instant and coordinated changes in transport scheduling and routing to avoid delays diffusing through the network.

Communications-based rail signaling systems maintain safety margins and aid overall management while increasing utilisation of rail infrastructure

Signaling systems can increase passenger capacity on the rail network and improve operating efficiency by reducing the time between successive trains. Conventional signaling systems detect trains in fixed sections (or ‘blocks’) of the track and protect the whole block from entry by other vehicles. This limits the minimum time between trains and restricts total passenger capacity. In communications-based (‘moving block’) systems, trains continuously communicate their exact position.

This information is relayed to other trains automatically, to adjust their speed while maintaining safety. This allows reduced distance between trains and increased capacity on the network. The San Francisco Municipal Railway (Muni) increased the capacity of light rail infrastructure from around 25 trains per hour under a fixed block signaling system, to 50 vehicles per hour using communications-based technology. The retrofit created additional capacity for peak travel periods and ensured improved flows of traffic from day-to-day.
Real-time coordination of urban transportation enables greater responsiveness to unforeseen events

Traffic control centers provide a centralised hub for data aggregation, analysis, predictive modeling and decision-making across the transport network. With visibility of traffic flows and blockages on routes throughout the network, control centers allow system operators to actively manage demand and optimise system capacity. The effectiveness of control centers relies on the presence of robust operational and information technologies installed along transport arteries throughout the city to monitor prevailing conditions.

Many cities operate control centers for individual modes or infrastructure types, such as buses or highways. For example, the Beijing Traffic Control Centre (BTC) monitors a network of 50 smaller Operational Control Centers for the various rail lines operating in China. The BTC integrates systems, including SCADA, operator information, CCTV, passenger data, decision support and incident evaluation to receive and aggregate real-time information while also sharing rail line data, rail line videos and reports with other stakeholders in the network. The system links to an Incident Evaluation System that triggers automatic or semi-automatic plans based on certain incidents, thereby ensuring that disturbances are resolved in a quick and coordinated way.

Some cities are exploring the use of cross-sectoral control centers that manage transport demand across multiple modes simultaneously, or which bring together multiple city sectors to enhance the city’s management capacity. For example, a state-of-the-art operations center is being developed in Glasgow, UK, which utilises more than 400 advanced digital cameras across the city to monitor traffic, emergency services and public security from a single location.²
Management of peak road traffic enhances vehicle flows and improves health

Congestion charging is a mechanism by which city authorities can manage the volume of traffic on city roads to improve vehicle flows and keep the city moving. Co-benefits include the opportunity to raise revenues and promote uptake of public transport. Congestion charging is in place in cities such as London, Stockholm, Oslo, Singapore and Milan, and can utilise a range of intelligent technologies such as CCTV with Automatic Number Plate Recognition (ANPR) to identify vehicles and their owners, and check against a database of those who have paid the congestion charge.

In Singapore, congestion pricing was introduced in 1975, charging drivers a flat rate for unlimited entries into Singapore’s downtown. Over time, the system was extended to cover expressways leading into the city, and was successful in achieving a 45% reduction in traffic and 25% reduction in collisions. In 1998, a more advanced system, the so-called Electronic Road Pricing (ERP) mechanism came into force. This reduced queuing around control gantries by allowing vehicles to pass at normal speeds, having already paid via registered smart cards installed with Radio Frequency Identification (RFID) technology. Since 1998, traffic has reduced by an additional 15% and public transport use has increased to more than 65%. Around 20–30% of total revenue is now allocated towards operating the system, and with annual revenue of more than $100 million, the ERP has already paid for itself allowing net profits to be invested in road maintenance and improvement. The ERP has also been successful in improving air quality and reducing journey times, which have contributed to making Singapore a healthier, more resilient city.
During the 2012 Olympics, and for the first time in London, TfL brought together multiple transport operators and the British Transport Police to control and monitor all aspects of transport under one roof. This union led to strengthened coordination between groups that had never previously worked together, which in turn enhanced the capacity of the whole system to run smoothly with heightened redundancy and capacity for responsiveness in the event of unforeseen incidents, congestion. The integration of multiple technologies was essential to the success of the control center. CCTV, VMS, road sensors, real-time data sharing devices, SCOOT and other technologies helped TfL manage the transport network and empower users to travel safely and efficiently between venues whilst also ensuring the efficient operation of the rest of the transport system. The control center is still in use during other major events in London.
Communication technologies allow transport operators to distribute detailed, real-time information to travelers about conditions on the network through a variety of media.

The increasing availability of data allows communications to be optimised for users’ needs, providing route planning and timetabling advice across multiple modes, as well as predictive models that take account of weather conditions, variable travel demands throughout the day, and events taking place around the city.

Communication technologies create increased coordination within and between systems, leading to greater efficiency in day-to-day operations. In the event of a sudden change in system status, improved access to information also enables greater responsiveness by system managers and users, enabling them to adjust the way they use the system and adapt quickly to new conditions.

Real-time travel information enables greater flexibility in travel decisions and can enhance network capacity by reducing congestion

A comprehensive network of sensors, monitoring equipment and communication systems installed in the transport network creates a greater opportunity for real-time aggregation and processing of data, and dissemination of accurate travel information to city travelers. Many transport authorities are already using VMS on roads and other infrastructure to publish up-to-date information about weather, congestion or blockages on the route, which allow travelers to change their course.

Traditionally, information is also pushed out via radio and TV channels. However, as the penetration of smart devices becomes greater, information providers are leveraging that connectivity to distribute real-time information about journey times and route options via SMS, internet and mobile apps.

A multitude of applications have been developed to gather information directly from travelers’ smart devices and from infrastructure. This information can alert drivers to accidents, road hazards, traffic jams and other blockages along the route. Others provide up-to-date travel information and notify users about closures or disruption to rail and bus lines.

Many of these apps disseminate different advice to re-route different users, ensuring that disruptions do not cause mass diversion of travelers on to a single alternative mode or route. The functionality of these services is afforded by data gathered through sensors and software and disseminated via smart phone and other devices. Studies show that drivers who use route-specific travel time information instead of area-wide traffic advisories can improve on-time performance by 5-13\%, while the use of in-vehicle dynamic routing systems can reduce congestion and provide additional network capacity.
Cooperative Road Systems promote communication between road users to optimise traffic flows and facilitate priority vehicles

Cooperative systems comprise of vehicle-to-vehicle and vehicle-to-infrastructure exchanges of information about vehicle speed, location and direction of travel; an example of the “internet of things”. This exchange can help to tackle road congestion by increasing the capacity and improve safety and environment. An alert can be generated to vehicle drivers when a potentially dangerous situation is foreseen, such as a collision ahead or adverse weather conditions. In addition to improving safety on the roads, cooperative systems can help road efficiency by using real-time data to inform drivers about traffic jams and route recommendations, resulting in savings in fuel consumption and CO₂ emissions from the existing fleet. Cooperative systems use a range of information and communication technologies, including wireless local area networks, cellular data and short-range technology such as Bluetooth. They can also be used to assist priority traffic light changes (a “green wave”) for emergency services vehicles. Vehicle-to-infrastructure communications have been trialed for 400 intersections in Harris County, Texas, using a simple traffic light control system that detects Bluetooth signals from emergency vehicles, triggering a green light that enables them to pass unimpeded.

Inter-operator Fare Collection (IFC) promotes flexibility and diversity in travel choices

Inter-operator Fare Collection, or smart ticketing, systems offer a user friendly and seamless way for travelers to transfer between transportation modes without queuing for tickets, promoting flexibility and adaptability according to changing travel needs or service conditions. Smart ticketing also brings benefits to service providers, allowing them to monitor, plan for and respond to traveler numbers in different parts of the network, and to manage fares through a coordinated central back office accounting system.

Smart tickets may require the traveler to actively scan their smart card into and out of an access control system at the start and end of their journey (a “Check-in/Check-out” system, or they may be contactless such that passengers can enter and exit the transport network without actively scanning their ticket (a “Be-inBe-out” system, currently under trial by Swiss Federal Railways). The passenger’s entry and exit points are automatically captured via radio frequency, as well as their location at different stages throughout their journey. Each eTicket contains a trip authorisation that is stored along with all relevant ticket information on the smartcard. When the ticket is checked, the eTicket is read using mobile readers or stationary control terminals. Payment may be taken by credit balance, direct debit or credit card, or anonymously using post-paid or prepaid payment options.
The Octopus ticketing system in Hong Kong is a joint venture between the city’s five major public transport operators. It allows customers to use a contactless smart card to access all modes of public transport, to pay for parking meters, car parks, convenience stores, restaurants, and supermarkets as well as to access residential and commercial buildings.

The Octopus system comprises four independent but interacting centers: the Central (Transaction) Clearing House (CCHS), the Service Providers Central Computer Data Processing System (SPCC), Service Providers Local Data Processing Equipment (LDP), and Contactless Smart Card Processing Equipment. The success of the system and its expansion into services other than transport is often attributed to its high acceptance level; supported by robust financial infrastructure, secure data collection and storage facilities and integrated telecommunications services, including Wi-Fi and smart phones. Among the benefits of the system is a reduced need for cash handling which formerly cost the transport provider nearly 1% of all revenue. The simplicity and multi-modality of the system has also enhanced its popularity, which has driven up revenues for the system provider, enabling it to re-invest, expand and improve the overall quality of the service. High levels of integration and alignment across multiple channels have produced a robust system that provides flexibility to travelers during an incident, and which enables system operators to remotely monitor traveler numbers across different parts of the network and prioritise their response during unexpected events.
Telecommunications Infrastructure

The technologies described on the preceding pages rely on the availability of a telecommunications infrastructure with the robustness and capacity to handle data and command flows over both short and long distances. This infrastructure includes copper and fiber cable networks and wireless transmission infrastructure including radio and microwave systems such as GPRS, 3G and 4G networks and Bluetooth.

Although wireless technologies can provide excellent flexibility, the evidence remains strongly in favor of the need for cabled networks to deliver the speed and capacity of data flows needed to operate the above technologies to their full potential.

The penetration of smart phones and similar devices in a particular city will influence the impact of some of the systems described above. As these become more ubiquitous, the opportunity grows for communication to take place not only from person to person, but also from object to object. The ‘internet of things’ describes the use of communication networks to link devices to each other, which – in a well-calibrated system – can implement commands and assemble essential information to maximise the effectiveness of human interventions and responses.

Cooperative Road Systems optimise traffic flows and promote responsiveness in city transport management

More than 2.4 billion bus passenger journeys are made each year in London. TfL operates a GPS-based technology called iBus, which uses SCOOT to collect data from in-vehicle detectors and enable prioritisation of bus services. For example, traffic lights may be phased to provide a lengthier green signal for buses, or the green phase may be reduced for other traffic. Alternatively, a whole light phase may be skipped to help maintain bus schedules and reduce congestion. The use of so-called ‘virtual detection points’ to compare the actual and scheduled locations of each bus means the system is less expensive to implement and less vulnerable to damage than traditional hard infrastructure systems.

iBus can also deliver information about the bus and its location to a central control center and to passenger information signs in bus shelters, enabling system monitoring and real-time journey planning.

TfL claims that bus priority services have helped to increase bus usage in the capital by 40% since 1999 and reduce delay periods by around 3-5 seconds per bus per junction. This has helped reduce fuel consumption and emissions, as well as adding to the overall efficiency and reliability of the bus system. Other benefits include:

- Passenger benefits through increased efficiency of the system;
- Revenues and short payback periods received by the service provider via; and
- Improved coordination and accessibility for emergency services.

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- Revenues and short payback periods received by the service provider via; and
- Improved coordination and accessibility for emergency services.
Ho Chi Minh is a city of modernity and tradition; growing affluence and persistent want. Nestled on the banks of the Saigon River, the city is at once a thriving metropolis boasting the many trappings of economic progress whilst bearing the scars of its chequered past and struggling to keep up with the ever growing demands of its rapidly expanding population. Ho Chi Minh City (HCMC) is Vietnam’s largest city by population and economic productivity, accounting for 23% of the country’s gross domestic product (GDP) and 20% of foreign direct investment.

Currently home to almost more than 7 million in the core and at least another 10 million people in the metropolitan area, HCMC is growing rapidly; expanding by 3-6% each year. Urban expansion predominates in the peripheral, rather than the core areas, leading to a sprawling urban form and rapidly growing demand for travel to the economic heart of the city.

HCMC is witnessing a dynamic phase of economic growth, industrial expansion and land-use change which is raising the city’s fortunes and attracting business opportunities and tourism alike. However, at such a rapid pace of transformation, the city is also facing a host of challenges from lack of housing and inadequate infrastructure, to poor air quality and severe transport congestion. Upgrading the transportation system represents a unique opportunity to improve resilience in all of the city’s future transport services, and create a more inclusive environment in which economic and social demands can be met.

**Review of weather related shocks and stresses**

The climate of Ho Chi Minh City is already extreme, and is predicted to become more so by 2050. The World Bank ranks HCMC as one of the ten global cities expected to be most severely affected by climate change.

There is high variation in rainfall throughout the year in HCMC, bringing both localised flooding and droughts. Climate projections suggest that total annual rainfall will remain stable, but seasonal variability is likely to increase, with extreme rain events becoming more common over time.

By 2050, it is forecast that the city’s population will reach 20 million.

In 2014, Vietnam is seeing the third fastest growth in smart phone ownership in the world, after India and Indonesia.

GDP in Ho Chi Minh City has grown by 10% per annum over recent years.
Historically, tropical storms were relatively rare in HCMC, but during the last 60 years more than 12 large tropical storms have affected the city, including Vae (1952), Linda (1997) and Durian (2006). These bring heavy rainfall, storm surges and increased local flooding, which have been known to reach more than a meter in depth. The city is highly exposed to fluvial, pluvial and tidal flooding, especially during the rainy season, but increasingly at other times of the year too. Of the city’s 322 communes and wards, nearly half have a history of regular flooding. These floods cover around 110,000 hectares and affect 970,000 people (12% of the HCMC population).

By 2050, the geographic extent of flooding is expected to be 3% greater for extreme events and 7% greater for regular events than current flooding scenarios. However, the increase in depth and duration of floods will be much more significant. Projected average maximum flood depth is expected to increase by 40% during extreme events and 21% during regular flooding, while the average duration of floods will increase by 12-22%.

Over the past decade, $1 billion has been spent on enhancing flood defense measures in HCMC. However, as the city expands and ever more people inhabit low-lying areas and flood plains, the bill for protecting the city’s assets will continue to rise.

Ongoing urbanisation may also increase the city’s flood risks. Lack of infiltration through hard surfaces, combined with clogged drainage systems and land subsidence place an increasing area of the city at risk. The fact that a significant proportion of future urban development is likely to occur in informal settlements, which tend to be located in lower lying areas, also increases citizens’ vulnerability to flooding.

### Flood-affected areas of HCMC, 2009 and 2050

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2050</th>
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</thead>
<tbody>
<tr>
<td>Number of communes exposed</td>
<td>154</td>
<td>177</td>
</tr>
<tr>
<td>Area of HCMC exposed (ha)</td>
<td>108,309</td>
<td>123,152</td>
</tr>
<tr>
<td>% of HCMC area exposed</td>
<td>54%</td>
<td>61%</td>
</tr>
</tbody>
</table>

### Rainfall in monsoon season is forecast to increase by around 10% between 2015 and 2050**

### Maximum volume of 180 minute rainfall events, 1952-2004**
Case Study: Ho Chi Minh City

Nevertheless, average traffic speeds in the inner core of the city are decreasing, from 18km per hour in 2002 to just 14km per hour in 2010. As car ownership increases and the city’s population continues to rise, the city is anticipating further congestion and severe traffic delays.

Even though roads are undoubtedly the predominant transport infrastructure, road management systems are not well developed, with traffic signals installed only at major intersections and little coordination enabled between them. The inadequate number of traffic surveillance cameras in existence (fewer than 50) communicate via a low-capacity Ultra High Frequency (UHF) radio channel leaving the transport police responsible for the manual control of the huge volumes of traffic that traverse the streets each day. As a point of comparison, Mexico City, whose population is similar to HCMC’s, has more than 8,000 cameras. With little public transport in place and car ownership growing in HCMC, the city is looking for ways to curb its progression towards gridlock.

In April 2012, Typhoon Pakhar destroyed more than 600 houses and schools across Ho Chi Minh City. The coastal district of Can Gio was the most severely affected. More than 3200 local people were evacuated.

Ho Chi Minh City is renowned for its transportation system, often perceived as chaotic and dangerous but with an essential, if esoteric functionality and efficiency. Motorcycles and mopeds are the dominant form of transport and, despite regular and often severe congestion, traffic continues to flow – albeit slowly – thanks to the small size and relative nimbleness of these vehicles.

To facilitate mode shift, the city is planning the construction of:

- Six metro rail lines (so-called MRT or Metro Rail Transit system);
- Three light rail lines;
- A Bus Rapid Transit (BRT) system.

All of these will be financed through a combination of local private and public funds, together with Official Development Assistance (ODA) from multilateral institutions including the World Bank, Asian Development Bank and Japan International Cooperation Agency (JICA). Work began on MRT Line 1 in 2012 and is due to be completed by 2018; work on Line 2 is expected to begin imminently.

This major transit investment program is the largest and costliest HCMC has ever seen, requiring the city to seek innovative financing mechanisms.

Damage from natural disasters over the last ten years has been estimated at 202 billion Vietnamese Dong ($12.6 billion).

<table>
<thead>
<tr>
<th>Mode share of Ho Chi Minh City</th>
<th>2015</th>
<th>2045</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bike</td>
<td>19%</td>
<td>15%</td>
</tr>
<tr>
<td>Motorbike</td>
<td>74%</td>
<td>60%</td>
</tr>
<tr>
<td>Car</td>
<td>1%</td>
<td>5%</td>
</tr>
<tr>
<td>Bus</td>
<td>4%</td>
<td>11%</td>
</tr>
<tr>
<td>Other (freight, taxi)</td>
<td>2%</td>
<td>9%</td>
</tr>
</tbody>
</table>

Speed measurements along roads in Ho Chi Minh City suggest that around 60% of total travel time is due to delay.

Car ownership in Vietnam is growing by 10% year on year.
Case Study: Ho Chi Minh City

Besides congestion, the dominance of road-based transportation leads to severe air pollution and safety concerns on city streets, as well as exposing HCMC’s transport system to acute and increasing weather-related disruption. As volumes of motorcycles and cars increase and traffic worsens, the city must find ways to reduce rising greenhouse gas emissions, which exacerbate human-induced climate change.

Currently, regular flood events are viewed with little concern by motorcycle riders, who tend to drive through the flood waters until engines flood or burn out. However, flooding is becoming increasingly frequent and extensive. As population and urbanisation rates rise, severe flooding will also increase the number of disruptions and the length of delays, which will negatively impact productivity and competitiveness and stymie economic growth27. Like many growing cities, HCMC is at an important crossroads in its development; implementing a modern, integrated and intelligent transport system would not only improve the city’s efficiency, but also its overall resilience.

Integration and resilience of the network

Alongside major investments in physical infrastructure (roads and rail), there is a need for improved traffic management in Ho Chi Minh City, reaching across all modes. Introducing the capability for real-time and remote intervention in network operations via an integrated traffic management system would enable more efficient day-to-day operation and an enhanced ability to manage disruptions during unforeseen events, such as flooding.

A range of transport technologies – including advanced traffic management and bus operation systems, smart traffic signals, digital cameras for street surveillance, GPRS, and advanced communication equipment – are proposed under current plans for infrastructure investments, for example those being funded by the World Bank and JICA. Integration of these components into a single holistic transport management system could yield significant benefits for the smooth-running of urban transport.

The Asian Development Bank predicts that, by 2050, flooding will affect all roads in HCMC, including highways, ring roads, axis roads and national roads, more than 50% of existing and 80% of planned intersections, plus numerous tertiary roads.

In addition, ADB expects that by 2050, 187km of railway, 33km of monorail and 36km of planned metro lines will be located in the anticipated flood zones, risking damage and disruption to all of these planned assets28.
If no investment in transport infrastructure is made, the number of delay minutes is forecast to increase by 620% over the next 30 years.

Proposed technical solution for HCMC Integrated transport management system

Based on the current situation in HCMC, a first step to improve the integration and resilience of the transportation system could be to establish an Integrated Transport Management System (ITMS), which would bring together all of the infrastructure and equipment required to manage traffic flows and the city’s transport system. This would include roadside infrastructure and the associated telecommunications equipment, along with a central control center responsible for the monitoring and management of the transport network in real-time. This system would comprise a package of solutions (see box).

Modularity allows for the introduction of further sub-systems in the future; a particularly relevant feature for a city with growing infrastructure. With each additional sub-system, there is an increased level of control over transportation performance, safety and environmental aspects.

In addition to operation, the system allows all data to be centrally aggregated and stored, enabling intelligent processing and analysis prior to distribution via public information platforms.

HCMC has some experience with traffic control centers, having previously installed two such solutions in 2003 and 2005. However, in 2013 the government announced its intention to close these operations following a litany of problems, including the loss of connection between traffic light sensors and the control center, as well as incompatibility of technologies resulting in poor integration.

Inter-operator fare collection

In addition to the ITMS, HCMC could also implement technologies to increase ridership on public transport. The adoption of an Inter-operator Fare Collection (IFC) solution (also known as smart card ticketing) with a check-in/check-out system could be implemented across all existing and future bus and rail infrastructure. While some provision has already been made for smart ticketing as part of the proposed MRT system, this has tended to be approached on a line-by-line basis. The fare collection system we propose would integrate all of the proposed schemes (MRT, BRT and buses) into a single multi-modal ticketing structure.

ITMS Strategy

The transport management system would integrate a modern Urban Traffic Control (UTC) system with modular sub-systems, including for example:

- Real-time control of traffic signals from one central location using a UTC system.
- Fiber optical connections or wireless mobile networks combined with Internet Protocol (IP) technology to transfer encrypted data from the controller to the central system. This would also distribute real-time traffic information to Variable Messaging Signs on the roadside, as well as TV, radio, and mobile applications.
- Induction loops, radar, magnetic sensors or Passive Infrared (PIR) to detect traffic volume and speeds including in some cases, vehicle types.
- Automatic Number Plate Recognition (ANPR) systems to identify the travel time of vehicles across a specific distance.
- Variable message signs (VMS) including full-matrix LED displays to distribute information to travelers about travel times and conditions on the route.
- Geo-referencing using data from devices installed across the city – including on vehicle counts, speed, parking space utilisation and weather – to map network conditions in real-time using Geographical Information Systems (GIS).
The HCMC bus system is expected to expand under plans for a new BRT network. Extending a smart ticketing system to the bus network would create a multi-modal capability similar to the London Oyster Card system or the Hong Kong Octopus. These schemes allow customers to deposit funds on their cards for later use, thereby reducing the need for and associated cost of ticket machines. The reduction or removal of paper ticketing reduces delays by lowering the queuing time associated with the cash fare; a delay which affects not only the bus or train, but all of the passengers already on it, thereby multiplying the impact of the delay.

At an average occupation rate of 20 passengers per bus, with a ticket purchase time of 5 seconds, there is a potential total delay of 100 seconds per passenger boarding a bus. Over a typical bus journey – which would have 60 passengers over the course of the route – this represents a saving of 5 minutes travel time per person. In addition, there are wider economic benefits to this saving, largely as a result of increased productivity.

A well-designed, integrated ITMS offers a number of benefits, including:

- Reduced congestion due to more effective traffic management, leading to reduced journey times, fewer delays and increased free flow of traffic around the city. The introduction of BRT in Buenos Aires, for example, reduced travel times by an average of 20-50%.
- Improved air quality as a result of less congestion and the associated pollutants which impact on health. The recently installed BRT corridor in Guangzhou, China is reported to have reduced carbon emissions by 45,000 metric tons in its first two years of operation; it is expected reduce particulate matter by 4 metric tons annually.
- Reduced numbers of accidents through more effective traffic signaling and the introduction of more advanced safety mechanisms for pedestrians. In New York City, the installation of a range of traffic signaling systems has decreased pedestrian accidents by more than 50%.

The benefits would be particularly prominent during times of severe weather, when the ITMS could create responsiveness in the transport system by monitoring network performance and communicating about delays in real time, allowing road users to bypass disrupted areas or avoid travel altogether. By assisting the free-flow of traffic and lowering congestion, the ITMS would also create reserve capacity in the system, for use in the event of sudden shocks.

By drawing a greater wealth of data from across the entire network, as opposed to a section of it, the ITMS would also assist operators in predicting and managing problems, ensuring quicker response times and increasing preparedness.

The integrated nature of this system would also offer a range of benefits that would be precluded from a disconnected or un-integrated system. These include: a greater capacity for control and manipulation by operators, greater ease of product integration (e.g. smartcards), greater capacity for data gathering and analysis and an increased opportunity for modal shift.

The HCMC Urban Transport Master Plan (HUTMP) aims to reach a public transport mode share of 40% by 2025.
Economic analysis

Note: all prices mentioned in this section are in US dollars and are discounted at a 10% discount rate, unless otherwise stated.

The economic analysis was designed to demonstrate the economic case for investing in transport technologies. Ho Chi Minh City was used as a case study to illustrate the benefits that could be achieved from these technologies in developing cities, and particularly those that are experiencing rapid population growth and increasingly frequent and severe weather events.

Our research suggests that the introduction of advanced ITMS and city-wide smart ticketing in HCMC would have an initial capital cost of $300 million, including optimism bias and the costs of capital. This figure accounts for all of the associated start-up costs, including information technology costs, infrastructure, training, the control center, and an optimism bias contingency factor to reflect the tendency of sponsors to underestimate system costs at a relatively early stage of development. Additional information on the cost assumptions used in our economic appraisal can be found in the appendices.

Our analysis concludes that the implementation and integration of certain advanced technologies (ITMS and IFC) would enhance resilience and support the development of the city’s transport network by improving robustness, redundancy, responsiveness and flexibility.

The analysis considered a range of scenarios including:

- A ‘do nothing’ option, in which current growth trends continue but no investment in additional transport capacity is made.
- The second scenario assessed the implementation of ITMS, compared with doing nothing.
- The third scenario investigated ITMS in addition to an extended Inter-operator Fare Collection system.

The third option assumed that current plans for the development of MRT were carried out as per the schedule proposed by the city.

The economic case demonstrates that the technology solutions merit their investment cost due to the benefits they deliver and the relatively short payback time. We found that the benefits would be experienced not only by public transport and road users through journey time savings, but also by the wider economy due to increased productivity and investor attractiveness. Improving the reliability and flexibility of the system would also result in enhanced resilience for the city as a whole. Specific findings of the analysis are outlined below.

Integrated Transport Management System (ITMS)

Our analysis revealed that investment in an ITMS would lead to improvements in traffic management efficiency. We expect that the benefits associated with an investment in this technology, when compared with a ‘do nothing’ scenario, would have a value of $2 billion over the next 30 years. The larger part of this benefit would come from delay reductions while a smaller portion would be seen in health and environmental benefits. Implementing ITMS will represent a significant benefit to Ho Chi Minh City’s economy, with the system taking only eight years to become net positive, after which the benefits increase sharply in line with predicted growth in traffic.

Savings in emissions and accidents from ITMS over 30 years compared with a ‘do nothing’ scenario:

<table>
<thead>
<tr>
<th>Emission/Issue</th>
<th>Reduction over 30 years</th>
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<tbody>
<tr>
<td>CO₂</td>
<td>400,000 tons</td>
</tr>
<tr>
<td>PMs</td>
<td>14 tons</td>
</tr>
<tr>
<td>NOx</td>
<td>1,400 tons</td>
</tr>
<tr>
<td>Road accidents</td>
<td>2.5%</td>
</tr>
</tbody>
</table>
The reduction in delay minutes and congestion achieved by the ITMS will in turn have a positive impact on the city’s economy. In HCMC, delays are expected to be three times longer during severe weather events than during normal conditions over the next 30 years. Our analysis suggests that on these occasions, the ITMS would enhance the city’s overall resilience by re-directing and managing traffic movements more effectively. This will lead to savings of over 87 billion delay minutes between 2015 and 2045.

$2 billion
Value of investing in ITMS compared to a ‘do nothing’ scenario.
Inter-operator Fare Collection (IFC)

The extension of the Inter-operator Fare Collection system to the bus network (in addition to the MRT) will lead to time savings for public transport users. Based on the forecast number of trips to be taken by public transport, the IFC is expected to lead to a saving of 22 billion minutes over the study period. These time savings have a value of $300 million to Ho Chi Minh City’s economy over that period. Taking into account the $141 million cost of the system and its operations, this results in a **benefit of $159 million**. According to our analysis, this system generates a net positive benefit from its inception in 2015, further reinforcing its value for money.

In the 'full investment' scenario (including both the ITMS and IFC), the total costs are expected to be $0.7 billion, meaning there will be an **overall benefit of $1.6 billion** to the city; the system will be net positive against costs in 2021.

The graph below represents the cumulative costs and benefits of implementing ITMS and smart ticketing together, compared with only introducing ITMS. Furthermore, the bar chart annotates the annual flow of costs and benefits for a combined ITMS and smart ticketing solution from 2015 to 2045.

The graph shows that an 'ITMS only' solution is expected to perform better than a 'full investment scenario' (ITMS and IFC) for the first seventeen years. However, by 2032 the benefits from the combined solution exceed the 'ITMS only' scenario, with the lines continuing to diverge into the future years beyond the study period. This clearly demonstrates that it is more advantageous to invest in an **ITMS and IFC solution**; this will secure the greatest benefits for the city in the **long term**.

By enhancing the efficiency and integration of the transport system, this project will also generate a series of wider economic benefits for Ho Chi Minh City. The ITMS and IFC solutions will contribute to lowering delays around the city, which will increase productivity and create longer term employment and GDP growth.

Economic analysis of the annual discounted costs and benefits for a combined ITMS and IFC solution, 2015 and 2045
To ensure business and trade can prosper, the city needs to maintain the right economic climate – this can be encouraged through investment in public transport. The ITMS and IFC investment is expected to have a positive effect on the city’s international image, leading to greater foreign investment, market competition and further tourism related revenues.

These investments will not only improve the day-to-day transport needs of the city, but ensure continuing growth and support economic resilience.

Financing transport technologies

To determine how to support investment in transport technologies, it is important to understand how the benefits are distributed among transport users; the fundamental assumption being that the primary beneficiaries should make a contribution to the overall costs (i.e. the ‘user pays’ principle). It should be noted that the financial case applies undiscounted costs and revenues in its methodology.

The predominance of motorbikes on the roads in Ho Chi Minh City would suggest that the greatest benefits would be received by these users. However, our analysis reveals that cars, freight and taxis will actually gain most of the benefits due to the greater distances they tend to cover and the greater contribution they make to road congestion.

Distribution of benefits among road users

Technological solutions such as ITMS may permit cities to establish entirely new revenue streams – such as congestion charging – using roadside equipment that is already specified as part of the system. As we have shown, revenues frequently outweigh costs for these types of project. Cities such as Ho Chi Minh City may use revenue surpluses either to finance new infrastructure projects entirely, or to seed fund new opportunities in order to attract external investment (e.g. development bank loans and private finance mechanisms).

Potential revenue streams

The undiscounted costs of both the ITMS and Interoperator Fare Collection system are expected to be $1.7 billion. There are a multitude of funding options that could potentially generate the revenues needed to support these solutions. Potential revenue streams include:

- Fare box (public transport) revenue
- Congestion charging
- Toll roads
- Parking charges
- Taxi license fees
- Vehicle tax increase
- Fuel duty increase
- Land value uplift
- Advertising.

Fare box revenues are typically leveraged to pay for the operation and maintenance of relevant systems, rarely providing a surplus. This is similar for toll roads and parking charges. Due to the large amount of signage associated with the ITMS, there is also the potential to generate auxiliary revenue from advertising. Given fluctuations in global advertising markets, this can be a high risk revenue stream however, and should not be relied upon to provide a long term or substantial source of income.

Since road traffic is forecast to increase between 2015 and 2045, and road users are expected to be the main beneficiaries from the ITMS scheme, a road user contribution will provide the most robust source of income in the case of a rapidly developing city like HCMC. The most appropriate revenue streams in terms of the potential magnitude of income available are therefore congestion charging, fuel duty increases and/or a vehicular tax increase.

Congestion charging

The London Congestion Charge scheme illustrates how a city can generate revenues which can be used to fund new initiatives related to the city’s road network. Since its introduction in 2003, the London scheme has generated a net revenue of $2 billion, which has been reinvested in bus network improvements, on roads and bridges,
road safety, local and sustainable transport and the environment\textsuperscript{41}. A similar scheme in HCMC would be highly beneficial and could be designed with sensitivity to detect two-wheeled vehicles.

Our analysis suggests that in HCMC, congestion charging would have a net income of \textbf{$790 million} – a significant contribution to the proposed technology investments.

**Fuel duty**

Our calculations suggest that the average fuel consumption per vehicle in Ho Chi Minh City is 14.5km per liter, rising to 19.5km as vehicles become more fuel efficient\textsuperscript{42}. An increase in fuel duty of $0.03 per liter (or 1.7\%) would lead to initial revenues of $145 million in 2015, generating a total revenue of $3.4 billion over the 2015-45 period\textsuperscript{43}. This revenue stream alone would adequately fund both ITMS and smart card systems. A local tax structure would ensure that revenues are reinvested in the local transport network rather than being absorbed by central government.

**Vehicular road tax**

Increasing road tax is another method by which cities can generate revenues for use in transport related projects. However, our analysis suggests that there are currently too few registered vehicles in Ho Chi Minh City to raise an equivalent scale of revenue as seen in the other examples above. The costs of implementing and collecting such a charge in Ho Chi Minh City only, rather than all vehicles in Vietnam, would likely exceed any revenues collected. This option would therefore only become beneficial once car use on HCMC’s roads becomes significantly higher.

**Funding appraisal**

It is apparent that a combination of the measures suggested would lead to a net surplus to the city of \textbf{$2.7 billion}, with the majority of this attributed to fuel duty revenues. While congestion charging is a high revenue generating opportunity, the costs of such a solution are also very high, which would lead to a net revenue of $790 million after accounting for costs.

This net surplus could be used to fund further infrastructure in the city and reduce Ho Chi Minh City’s reliance on development bank financing, which has high interest rate charges.

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### Funding Strategy Summary Results 2015-2045

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<thead>
<tr>
<th>$million (2012 prices, Real)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total costs</strong></td>
</tr>
<tr>
<td>ITMS &amp; IFC costs</td>
</tr>
<tr>
<td>Congestion charge system</td>
</tr>
<tr>
<td><strong>Total revenues</strong></td>
</tr>
<tr>
<td>Congestion charge revenue</td>
</tr>
<tr>
<td>Vehicle tax revenues</td>
</tr>
<tr>
<td>Fuel duty revenues</td>
</tr>
<tr>
<td><strong>Net surplus</strong></td>
</tr>
</tbody>
</table>

\textbf{Road map for transport resilience in Ho Chi Minh City}

In addition to identifying technology investments that would help HCMC to meet its future transport needs and enhance resilience, we have also examined the enabling actions required to support implementation. An enabling framework for HCMC would include arrangements to facilitate effective cooperation between groups and stakeholders at various levels of city administration, ensuring the development and delivery of an integrated multi-modal transport plan.

This may require updated policies to guide urban planning, the evolution of new agencies to coordinate cross-sector activities, the training of staff to operate new equipment and analyses the output data and trends, and the pursuit of new approaches to secure alternative sources of funding.
HCMC will also need to promote operational integration through technology standards and protocols. The design and operation of each line of the multi-phase MRT system will be defined by a range of international and local standards set by the donor financial organisations. Since there is no common standard among these groups, there are concerns regarding the compatibility of equipment and the integration of technologies with one another and under a single control center. The United Nations Development Programme (UNDP) has suggested that the use of multiple funders may mean that the implementation of projects could be delivered less on the basis of transport needs or to a schedule that would connect areas in the most beneficial way for the city, but rather according to the individual interests and obligations of each donor. If misalignment in standards and expectations is not addressed, delays – or even failure to complete some lines – may be expected. HCMC authorities must ensure that, if the systems cannot be built to the same standards, they must be capable of cooperating.

The actions listed in this road map are not unique to Ho Chi Minh City and may be appropriate within the context of any city, regardless of infrastructure age or scale of operation. They are particularly pertinent, however, to cities like HCMC with significant weather related hazards and a large proportion of transport mode share dominated by two-wheelers.
5 Enabling Framework

Our survey of urban transport system technologies and the Ho Chi Minh City case study have shown that the use of technology solutions to create resilience is possible – and effective – only where a set of supporting instruments is in place, in the form of planning, policy, operating protocols, governance, knowledge and financing.

Planning, policy and physical infrastructure

The effectiveness of transport technologies is dependent on robust infrastructure design and effective planning and regulation.

Transport technologies are an additional system overlaid onto the physical infrastructure. While their function is to improve the performance of physical infrastructure, they are themselves vulnerable to physical damage or malfunction if the underlying infrastructure itself is poorly planned, designed or constructed. If transport facilities are constructed in flood-prone areas and designed with insufficient drainage or flood protection, the installed technologies will likewise be highly exposed to damage or destruction.

Therefore, the effectiveness of transport technologies is dependent on appropriate urban planning and robust infrastructure design, to ensure that transport systems are appropriately protected. This requires land use planning and policy that is sensitive to existing and emerging environmental risks, and codes and regulations which are effectively enforced. The use of vulnerability assessments is becoming increasingly common for cities to understand the specific risks associated with infrastructure assets, neighborhoods, and other aspects of the city.

The objectives of transport technologies can be supported by integrated transportation planning and policies.

This report has demonstrated that transport technologies can help to manage transport demand and supply in cities through improved monitoring and management across modes. This, in turn, can help to reduce urban traffic congestion and the adverse environmental, health and safety outcomes that congestion can cause.

The effectiveness of technology interventions to achieve these outcomes is strengthened by the use of complementary policies to promote modal shift and reduce travel demand. For example, many cities – including Ho Chi Minh City – are making substantial investments in the quality, comfort and convenience of their public transport services, pedestrian and bicycle infrastructure, with the objective to distribute passengers across more modes and reduce the sometimes disabling congestion caused by private cars and motorbikes.

Increasing the reach of public transit services is one of the most frequently cited actions reported in a recent C40 Cities survey of its 63 member and affiliate cities.

Some cities have taken more extreme measures to improve traffic flows. For example, Bogotá, Colombia, held its first completely car-free day in February 2000, which later became institutionalised through public referendum. Bogotá currently holds the world’s largest car-free weekday event, which covers the entire city. Other cities – like Beijing – have opted for solutions such as road space rationing, which artificially restricts demand for vehicle travel by reducing the available road space either permanently or during specific peak periods. In permanent solutions, space may be reallocated to other road users or for public open space.

Therefore, while technology should play a clear strategic role in transport management, the alignment and operation of policies and physical infrastructure management systems is essential.
Technology standards and protocols

Transport technologies should be interoperable, ensuring that individual components can work together as part of a cohesive system.

Creation of an integrated and interoperable transport system is facilitated by a city wide strategy for transport technologies, which ensures that a holistic and coordinated structure is created as opposed to ad hoc individual technical components.

Technologies are manufactured and installed by a wide range of providers from across the world, often adopting different specifications for design and operation. While these variations serve to enhance functionality, drive innovation and promote economic competitiveness, without deliberate interoperability design standards they can also inhibit the development of cohesive, integrated systems.

Technologies with different origins are not always compatible with one another, and can be difficult to incorporate into a networked system. This is a particular challenge for cities which experience piecemeal transport investments implemented through multiple agencies and/or funding bodies. In growing cities like HCMC, where infrastructure and technology is evolving rapidly and unevenly and where fewer standards and protocols have yet been established, it is a challenge and a necessity to bring systems under the influence of shared guidelines.

Common standards and protocols contribute to the efficient running of all urban systems, enabling data to be aggregated and shared from different sources. Standards can also drive safety, reduce costs and improve environmental impacts. The compatibility of assets and equipment also drives resilience by providing robustness and the capacity for assets to support one another, creating flexibility and redundancy.

A number of international standards exist for intelligent transport systems, although slightly different standards have been adopted in different regions of the world. City and national governments should make an informed decision about which standards they will specify for their systems, to ensure uniformity in tendering processes and procurement.

The compatibility of legacy systems should also factor into this. Transport technologies are rarely introduced in a completely “green field” setting, and existing systems will require integration, upgrading or replacement. Rigorous system testing may be necessary to ensure that systems are working properly following integration of new components.

Standards and policies should be in place to govern data collection and sharing, to secure personal details and protect privacy.

Questions of personal privacy and data confidentiality have broadened and magnified over recent years as the use of smart phones and social media has increased. While the benefits of big data have been widely recognised, many people remain concerned about loss of control over personal information.

Global standards guiding and governing the collection and sharing of data are varying in their scope and stringency. Development of data management processes and regulations for data exchange and sharing require cooperation from government, private sector and individuals. Standards should be considered concurrently with the employment of intelligent technologies, and should ensure the mutual benefit of the user and the system.
Integrated Governance

Technical integration of infrastructure and services should be mirrored by human integration of planning and decision-making authorities.

While technologies help to create operational integration between components of the transport network, they will not be fully effective unless the value of integration is recognised and reflected by the agencies and authorities that control and influence the network. Integrated planning and decision making requires active sharing of information and coordination between agencies. Organisational integration implies shared access to the data and information generated by field devices and analyses, to ensure that all agencies are taking mutually supportive decisions on the basis of up-to-date and sound evidence. Operating protocols, security clearance and formalised data sharing procedures are critical to this process.

Changes in day-to-day working practices, reporting hierarchies, and – in some circumstances – physical location may also be required to facilitate closer consultation between stakeholders. Formal agency responsibilities, policy mandates and budgetary controls may be reviewed to avoid narrow definition of roles and failure to coordinate with other interested parties.

Case study: National ITMS Architecture, USA

The National ITS Architecture is a guideline prepared by the United States Federal Government, to define a standard national interoperable intelligent transport system structure. Introduced in 1994, the guideline provides a common framework for planning, defining and integrating ITMS. The architecture defines:

• The functions that are required of ITMS (e.g. gather traffic information or request a route).
• The physical entities or subsystems where these functions should reside (e.g. in-vehicle or in the field).
• The information flows and data flows that connect these functions and physical sub-systems together into an integrated system.

The National Architecture is an evolving guideline as new user services are developed, standards progress, and more ITMS implementations put the architecture into action.

Case study: Trafikverket, Swedish Transport Administration

In 2010, the Swedish Government took the decision to integrate its four transport agencies to increase efficiency in transport planning and operations nationwide. The new agency, Trafikverket, was established with a remit covering road, rail, maritime and air traffic. The Administration is responsible for:

• Long-term planning of the transport system across all four modes;
• Construction, operation and maintenance of the state road network and national rail network;
• Promoting accessibility in public transportation, for example through the award of public service obligation contracts on a national level;
• Examining applications for state grants to the maritime shipping sector.

Through a single administration, decision making is streamlined and integrated long-term planning is more easily negotiated.
Knowledge, Behavior and Skills

Transport operators must have the skills and capacity required to operate, manage and maintain transport technologies to ensure their effectiveness.

While intelligent transport systems are highly beneficial, they are also complex. Installation, operation and maintenance of central systems, the communication network and outstations require technical skills and a depth of knowledge that incumbent transport operators may not possess, and which can take time and targeted assistance to acquire. Likewise, data collection, aggregation and analysis also demand a distinct set of skills, without which city transport authorities may not be capable of operating the system to its full potential or effectiveness.

A handover and capacity-building process should be incorporated into tenders and supplier contracts, to ensure that technology providers offer cities a full program of training and assistance in the commissioning and medium-term operation of new technology applications. In some cases, suppliers may assign technicians to the city on a temporary basis to support adoption and maintenance of technology systems.

Training should be provided to local operators on an on-going basis to ensure continual updates in knowledge, particularly in line with new software developments and hardware renewals.

Travelers must be willing to alter their normal behaviors in accordance with policy incentives. While technologies can foster system integration, improve traveler convenience, and promote mode shift, its effectiveness is limited by the willingness of individuals to make use of new systems and services, and to change their travel behaviors. For example, provision of a city-wide Mass Rapid Transit (MRT) system or real-time service information will only have an impact on urban mobility characteristics if people are prepared to use the services they offer. Behavior change is a real concern for cities with long – and deeply – entrenched norms, such as motorbike use in Ho Chi Minh City.

Behavior change depends substantially on the level of awareness and understanding that individuals have about the services available to them. The introduction of any new public infrastructure or public-facing services requires accompanying promotion and education to draw a critical mass of users.

By increasing access to travel information and services, individual travelers are better prepared to take decisions that can bring large-scale change in the transport system, including reduced congestion. Trading on the congested nature of Vietnam’s streets and the difficulties of hailing a cab in person, taxi booking apps are starting to improve access to much-sought-after private vehicles. The German start-up ‘EasyTaxi’, its Malaysian rival ‘GrabTaxi’ and Vietnamese counterpart ‘PingTaxi’ provide platforms to which existing taxi drivers can subscribe and travelers can find, book and pay for a vehicle via smartphone, without lengthy wait-times on the street. The apps may help to ease congestion by reducing vehicle circling or idling.

While the existing players in the market have gained small penetration, the international megabrand ‘Uber’ also announced its arrival in Vietnam from July 2014, providing greater diversity at the luxury end of the private hire market.
Finance

Consider innovative revenue generation and financing methods.

It is no secret that the installation of a city wide transport management system comes at a high price, which can be difficult to recover directly from a dispersed group of direct and indirect beneficiaries. As with any public infrastructure investment, the cost does not end upon commissioning. Operation, maintenance and renewal costs are as significant for digital infrastructure as they are for physical engineering, and must be foreseen (and the risks reduced) as part of the initial investment.

The investment model outlined earlier in this study presents just one scenario to describe how costs for specific transport technology solutions could be covered by a variety of sources, including user fees, local taxes and charges, private finance, multilateral assistance, and public subsidy. This study deliberately addresses solutions – ITMS and the Inter-operator Fare Collection system – that could be integrated into existing plans for the expansion of the transport network in HCMC.

Although user fees and taxes are unlikely to cover the full capital and operational cost, they should be maximised to secure the long-term sustainability of the system. Cities should consider innovative sources of revenue generation, particularly those that can be newly accessed through the use of transport technologies and combined with behavioral incentives to travelers. Congestion charging, road user fees (such as tolls), dynamic parking fees and automatic season ticket renewals are a few examples that can help to secure the flow of revenue required to support the system.

Cities have also sought to capture new revenues from the uplifted land values that occur in the area surrounding improved transportation services, for example through parking fees, tax increment financing and community infrastructure levies. Debt financing initiatives have also been introduced by some city and national governments, who are selling bonds to generate revenue for investment.

Private finance initiatives are becoming increasingly common in the arsenal of financing options available to transport project developers. Contractual arrangements with private funders are varied, including Build-Operate-Transfer models (BOT), Build-Transfer (BT), Build-Transfer-Operate (BTO), Build-Operate-Own (BOO), and franchise contracting mechanisms.

Private finance has the benefit of securing long-term, specialist project management by an entity with vested interests in ensuring financial success. Private financiers will need greater certainty from governments about the risks and benefits of public projects – as considered below.

Clarify public funding regulations for service-oriented projects.

The capital and operational costs of implementing an integrated transport management system are significant, and can be difficult to evaluate against the expected benefits of improved service. The evaluation process for public projects is often focused on financial return on investment, and rarely includes criteria for less tangible or quantifiable conditions like environmental and quality of life improvements. Specific characteristics of resilience – such as redundancy – are often opposed to the financial imperative for efficiency and reduced operational costs. These considerations can make service-oriented projects difficult to justify through public funding procedures.

To resolve this constraint, there is a need to adjust funding regulations, investment reviews and procurement processes to place greater value on services that may offer long-term and widespread benefits to the economy, society and environment. These benefits are increasingly taken into account by multilateral funding institutions through mechanisms such as the Equator Principles; however few governments have yet taken steps to do likewise.

This study has quantified social and environmental benefits in economic terms, to demonstrate how they stack up against economic costs. Our hope is that similar investment analyses may become more commonplace in public funding decisions.
In some cities, local governments have created independent investment companies, such as Ho Chi Minh City’s Investment Fund for Urban Development (HIFU). HIFU is a state financial institution operating as a fully legal entity with an independent accounting system, covering its own costs and at its own risks. The institution is responsible for generating capital and allocating funds through loans to and investments in infrastructure projects, including key transportation improvements and other civil works. Revenue is generated through a combination of mechanisms, including loan syndication with banks, project and municipal bonds and foundation of joint-stock companies operating in project investment. At its foundation in 1997, the fund totaled nearly $13 million, rising to $39.75 million by the end of 2003. Given the operating successes of HIFU, Vietnam has set up 12 similar investment funds in other provinces.
Appendix 1: Details/Assumptions of Economic Analysis

An economic appraisal was undertaken to demonstrate the economic case for investing in integrated transport technologies as a strategy for resilience. Two systems have been analysed; an Integrated Transport Management System (ITMS) and Inter-operator Fare Collection (IFC) to cover the bus network. The analysis examines the impact that these technologies will have on disruptions from severe weather, congestion and traffic delays in the city, measuring this against the value of the population’s time in Ho Chi Minh City in order to determine the magnitude of the benefits. This analysis also includes the impact of these reduced delays on road traffic accidents and pollutant emissions, and pays particular attention to the performance of the system in cases of extreme weather.

As demonstrated in the figure below, the appraisal examines a ‘do minimum’ scenario which establishes the base case against which the ‘do something’ options can be analysed. These ‘do something’ cases represent the implementation of the ITMS or IFC, and ITMS and IFC together.

The analysis has been structured with the costs and benefits forming inputs to the economic appraisal model, analysing the ‘do something’ cases against the ‘do minimum’, which leads to a series of cost benefit outputs – benefit cost ratio and net present value – for each option. These outputs also inform the funding analysis which outlines various ways in which the proposals can be paid for. The diagram below represents this process. The appraisal takes into the account the MRT system which is currently under construction, with the planned six metro lines and three light rail lines.

**Economic appraisal scenarios**

- **Do Nothing**
  The city continues growing as is, with road congestion increasing as forecast.

- **Do Minimum MRT**
  The MTR system is developed
  - Decrease in delay minutes

- **Do Something ITMS**
  ITMS implemented without the MRT system
  - Decrease in road congestion
  - Value of time savings
  - Reduced accidents
  - Improved air quality

- **Do Something IFC**
  Time savings for bus and MRT users
  - Reduced congestion
  - Value of time savings
  - Time savings on MRT and bus

- **Do Something ITMS & IFC**
  - Decrease in road congestion
  - Value of time savings

Optional Case

Case 0

Case 1

Case 2

Case 3

Case 4
The MRT is expected to draw private vehicle users off the roads, thereby leading to a reduction in the total number of road related trips. However, it should be noted that the characteristics of a new MRT system are such that many of the trips forecast are the result of new user journeys, rather than road users moving from their own vehicle onto the public network. In the first years of its operation, the MRT is expected to reduce the number of road users, leading to fewer road related trips. The number of trips by road are then forecast to increase at a similar rate as the ‘do nothing’ scenario until 2045.

Benefits
The magnitude of benefits in the economic appraisal is mainly dependent on the traffic growth projections for Ho Chi Minh City – this has been forecast with a large increase in car traffic, taxi and bus traffic, with a diminishing number of motorbikes. This reflects the trend often experienced in developing countries for car ownership to increase in line with GDP per capita growth. In HCMC, a ten-fold increase in car trips is expected by 2050, while the number of trips by motorbike is forecast to decrease by 46% in the same period. This will lead to greater congestion due to the larger relative road space footprint of a car compared with a motorbike and the increased comfort of a car which tends to encourage people to take longer journeys. As traffic grows over time, additional congestion will be experienced, meaning that investments in technology solutions will bring the greatest benefits during this period. In the economic appraisal, congestion has been analysed using delay minutes as the primary measure – a delay minute being the time one spends delayed due to congestion as compared to free-flow conditions.
The value of the benefits of the ITMS during normal conditions and extreme weather can be calculated by examining the direct impact of road traffic on drivers in terms of time lost due to travel, basing this on each mode's unique value of time. There is also an indirect economic impact on households, from road traffic delays; this is as a result of business passing on the associated costs to consumers in the form of higher prices of goods and services.

This congestion has an economic value and is tied to each mode of transport's 'value of time': the opportunity cost of the time that a traveler spends on his/her journey. This is in effect the amount that a traveler would be willing to pay in order to save time, or the amount they would accept as compensation for lost time.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Value of Time per Minute (2012 prices)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bike</td>
<td>0.03</td>
</tr>
<tr>
<td>Motorcycle</td>
<td>0.06</td>
</tr>
<tr>
<td>Car</td>
<td>0.21</td>
</tr>
<tr>
<td>Freight</td>
<td>0.21</td>
</tr>
<tr>
<td>Taxi</td>
<td>0.15</td>
</tr>
<tr>
<td>Bus</td>
<td>0.06</td>
</tr>
<tr>
<td>Metro</td>
<td>0.09</td>
</tr>
<tr>
<td><strong>Net surplus</strong></td>
<td><strong>2,705</strong></td>
</tr>
</tbody>
</table>
The appraisal analyses the difference in congestion related delay between the ‘do minimum’ and ‘do something’ scenario, generating the total amount of delay minutes saved due to intervention. These delay minutes further inform the environmental assessment and road safety assessment, with the amount of pollutants and road accidents related to delay minute savings.

The environmental assessment includes a reduction of particulate matter (PM) and NOx (mono-nitrogen oxides), which both have severe impacts on human health, by reducing these health hazards and improving the rate of road traffic accidents this may improve the cities global ranking and lead to a far more resilient urban economy, attracting foreign investment and driving growth.

In the graph opposite, the primary axis (left) representing NOx and PM, and the secondary axis (right) representing CO2 savings.

Furthermore, the appraisal analyses the reduction in accidents expected in the ‘do something ITMS and IFC scenario. This includes a 2.5% reduction in accidents, with a reduced number of fatalities and serious injuries. These categories of accident have different economic values, with fatalities representing the lost output of that individual over their lifetime, and serious injury accounting for the temporary lost output of the individual and their healthcare costs. These values have been determined using global benchmarks, along with values from the developing world, and grown according to Ho Chi Minh City’s GDP.

The appraisal of the IFC has taken into account the bus network only, reports on the MRT system have highlighted that it will have a smart ticketing system included, which will have been analysed in a separate business case, and therefore should not be accounted for in this analysis.

We have assumed that the smart ticketing will lead to savings of 5 seconds per bus passenger due to the reduced need to pay by cash – this saving is valued using the bus passenger value of time highlighted in the table above. However, any delays in boarding a bus not only impacts the person boarding, but also all of the passengers already on-board, delaying their journey. Therefore, the value of these savings will be significantly higher due to reduced bus dwell time at stops. The appraisal assumes an occupancy
factor of 20 passengers, therefore a saving of 100 seconds per passenger, per average trip. As highlighted in the analysis this is expected to have a benefit of $300 million, 2012 prices and discounted.

However, it is worth noting that the time savings for such a technological intervention are dependent on the number of users. According to the forecasts in the analysis, bus users are forecast to increase over time with a total of 12.8 billion trips over the next thirty five years. This suggests that this solution will have enormous benefits for Ho Chi Minh City through journey time savings. With a discounted cost of $141 million over the study period, it is apparent that smart ticketing is a high cost and high value proposition.

Costs
The capital costs of the ITMS at $616 million, along with the operating costs, will likely be financed using project finance, in this case a PFI mechanism. This form of financing has an associated annual interest payment, which in this case has been included in the total capex figure quoted above.

While the interest payments seem relatively high in relation to the overall costs, this will alleviate any risks related to construction and operation which would previously have fallen upon the public sector. An ITMS system in a developing city such as Ho Chi Minh City, coupled with the severe weather occurrences, increases the risk beyond what would be envisaged in a European city which has previously developed ITC infrastructure and has the technological skill to build and operate it successfully. This makes a less risky project finance structure more attractive.

The following table outlines the key components of the traffic management system that have been included in the cost analysis for this study. As can be seen in the table, the capital costs include a significant amount of new infrastructure, including 3000 cameras, 910 new signals and 6000 sensors, along with variable message signing at every major gateway to the city. This level of spending will provide a comprehensive new system for the city and will lead to the maximum amount of benefits, as highlighted in the appraisal. Furthermore, these capital costs will include the data center to communicate with this infrastructure, as well as the hardware and systems to populate the center.

It is worth noting that capital expenditure includes all related renewal costs for the system between 2015 and 2045 – this are expected to be high as the extreme weather in Ho Chi Minh City will impact the systems performance significantly more than a similar system in a stable climate.
Furthermore, an ITMS system such as this is expected to have operating costs of approximately $97 million between 2015 and 2045. The operating costs are accrued annually and account for the operation of the system, including staff costs, IT and administration, and utility costs. Renewal costs are also expected as the system technology becomes outdated and requires upgraded. It is critical that a system such as this is maintained and renewed to a high standard in order to prevent failures in such a demanding environment as Ho Chi Minh City, and that the technology in this rapidly advancing field is kept up-to-date which could affect traffic flows and the transport network.

The Inter-operator Fare Collection system is expected to have high initial capital costs which are related to the significant retrofits required for gate lines, ticket machines, ticket offices and retailers to ensure compatibility. Alongside this, there are considerable operating costs to consider. The London Oyster Card system was procured under Public-Private Partnership between TranSys and Transport for London, at the cost of £1.1 billion over 17 years. In Ho Chi Minh City the total costs of the system between 2015 and 2045 have been forecast at $1.0 billion (discounted), a figure which has been benchmarked against similar systems.

<table>
<thead>
<tr>
<th>Components</th>
<th>Purpose</th>
<th>Costing Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital surveillance cameras</td>
<td>To monitor the network</td>
<td>3000 cameras in the network.</td>
</tr>
<tr>
<td>Traffic signals</td>
<td></td>
<td>910 new traffic signals</td>
</tr>
<tr>
<td>Sensors</td>
<td></td>
<td>6000 sensors in the overall network</td>
</tr>
<tr>
<td>Variable Messaging Signage (VMS)</td>
<td>To communicate to travelers</td>
<td>Located at every major city gateway.</td>
</tr>
<tr>
<td>Dedicated cameras for enforcement (e.g. with Automatic Number Plate Recognition)</td>
<td>To enforce regulations such as speed restrictions, road user charges, etc.</td>
<td>Located at strategic transport junctions. This component requires further cost assessment.</td>
</tr>
<tr>
<td>Fiber optics</td>
<td>To transmit data and information from point to point</td>
<td>Wider city related fiber optic infrastructure has not been accounted for in this system.</td>
</tr>
<tr>
<td>Control center premises</td>
<td>To house the main control center</td>
<td>Including space for all IT infrastructure, staff facilities, work areas etc. These components require further cost assessment.</td>
</tr>
<tr>
<td>Software interface (for data import, analysis, export)</td>
<td>To aggregate, process and analyses transport data</td>
<td>Based on previous project experience. This requires detailed project specific cost analysis.</td>
</tr>
<tr>
<td>Hardware (e.g. computer equipment, screens)</td>
<td>To display visual information about the network</td>
<td></td>
</tr>
<tr>
<td>Staff</td>
<td>To operate the control center, take decisions and distribute information</td>
<td>150 staff will be required to operate this comprehensive control center.</td>
</tr>
<tr>
<td>Training costs</td>
<td>Extensive training of control center staff to operate the equipment and maintain the system.</td>
<td>To be determined at full business case level.</td>
</tr>
</tbody>
</table>
These results have been used to inform the potential funding strategies for the ‘do something’ ITMS and IFC scenario. Further information on this can be found in the main text, section 4.

Operating costs
As mentioned above, the ITMS is expected to have operating costs of approximately $97 million between 2015 and 2045. The operating costs are accrued annually and account for the operation of the system, including staff costs, IT, administration, and utility costs.

Operating costs are expected to be approximately $9 million per year, 2012 prices, real. The graph below illustrates the system operations costs over the study period in 2012 prices and discounted. When discounted they decrease from $9 million in 2015 to $1 million by 2035.

The operating costs appraisal have been calculated at a high level, considering the scope of this study. However, we expect that an ITMS and IFC system would require approximately 150 staff (full-time equivalents, FTE). The ITMS control center would be required to operate around the clock, with three shifts of 8 hours. Of the 150 staff, 50 will be employed for IT and administration functions to support the operations of the traffic management center.

The remaining 100 full time equivalents will be spread out through the day, across three shift patterns. It is imagined that more FTEs will be required during peak travel hours, when traffic is at its busiest. Therefore, there will be 37 FTEs during these periods, and 26 FTEs during off-peak. The analysis is based on the staffing requirements for London-based traffic centers. This staffing analysis has been assumed separate of the operating expenditure calculations and is only indicative of the scale of staffing such a center will require.
Appraisal results

The table outlines the various scenarios which have been analysed as part of the economic appraisal—ITMS only, IFC, and ITMS and IFC.

All prices are discounted in line with economic appraisal standards. The discount rate is 10% which is an appropriate figure for the developing world—in a European context one would expect a discount rate of 3-3.5%. Benefits accrued are worth more in the present year, than in twenty years for example; in standard appraisals a discount rate is applied which factors there future benefits down in-line with present values. The total figures determined over the period can be described as the 'net present value'.

The results at this strategic outline stage suggest that all three scenarios offer good value for money with Benefit Cost Ratios (BCR) above 2:1\(^\text{ES}\), offering significant benefits to the Ho Chi Minh City economy.

<table>
<thead>
<tr>
<th>Economic Appraisal Summary Results 2015 – 2045</th>
</tr>
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<tbody>
<tr>
<td>$m (2012 prices, discounted)</td>
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<tr>
<td></td>
</tr>
<tr>
<td>ITMS</td>
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<tr>
<td>Costs</td>
</tr>
<tr>
<td>Delay savings</td>
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<tr>
<td>Journey time savings</td>
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<tr>
<td>Emissions savings</td>
</tr>
<tr>
<td>Accident reduction</td>
</tr>
<tr>
<td>NPV</td>
</tr>
<tr>
<td>Benefit Cost Ratios (BCR)</td>
</tr>
</tbody>
</table>
Appendix 2: Recommendations for Traffic Management Systems

Road traffic is one of the most important modes of transportation in all major cities around the world and in particular Ho Chi Minh City. A well-functioning network represents a significant success factor for economic and social viability of the city. However, existing road network capacity is becoming limited and growing cities are struggling to address congestion on the network. This implies additional challenges in terms of safety, security and environmental factors such as air quality and noise. In Ho Chi Minh City, the development of new BRT and MRT systems is aimed at tackling the city’s increasingly severe road capacity challenge, not to mention increasing car ownership.

Traffic Management is the logical result of optimising a city’s traffic situation by utilising the limited available (road) capacity. While a modern Urban Traffic Control (UTC) system is usually able to improve traffic flow with positive effects on safety and the environment, a traffic management system connects a modern UTC with other subsystems to enable city-wide traffic strategies for optimal handling of all transportation needs. With the integration of each additional urban system – such as variable message signs (VMS), parking guidance systems and traffic information portals – the degree of control over transportation performance, safety and environmental aspects increases. Information can be acquired and shared across systems, and control measures can be implemented using various methods. An integrated system in HCMC would connect technologies drawing data from the bus, road and metro-rail systems, providing greater transparency in the event of shock incidents and greater efficiency on a day-to-day basis.

Traffic management systems are highly beneficial, but they are also complex. Daily operation requires qualified personnel and competent planning, as well as maintenance of the central systems, the communication network and the outstations. Installation and construction of the central system and subsystems can also be a technical challenge for many cities. The implementation of a traffic management system rarely happens on a “green-field” site, so existing systems must be integrated, upgraded or replaced. For both phases – implementation and operation, the careful selection of technologies, systems, vendors and service providers is an essential factor.

This appendix contains key recommendations for implementing an Intelligent Traffic Management Systems in HCMC.

A common platform
An effective Intelligent Transportation Management System (ITMS) will have a common integrated platform that centrally coordinates traffic strategies for the efficient balance of Mobility, Safety and the Environment. Multiple subsystems address the different traffic management needs of a city and a suitable Traffic Management Platform enables the operator to centrally operate all outstation devices and systems.

Modular structure
A modular structure enables the functionality of the system to be tailored exactly to the current requirements of HCMC, thus allowing it to grow in line with the future needs of the city. The system should support a selection of existing modules and also allow newer applications to be integrated as the technology evolves.

Data storage
The ITMS will allow data including status messages from on-site installations and systems to be aggregated and stored in one location. This enables the system to generate central maintenance notifications for service personnel, which is a key function for faster and more efficient maintenance of all field devices and systems. This data should also be available for all subsystems enabling intelligent processing of traffic data for distribution and public information via a web-based information platform, but also for extensive traffic analysis to identify critical locations and improve transportation planning and traffic flow.

Geographical Information System
For a better overview of the overall system, a display of a detailed map is highly convenient, including roads, road names and background/terrain information as e.g. rivers, building areas etc. A suitable digital map of the road sections containing all desired information should be derived from existing map material, which would then be used in the new traffic management system.
An integrated GIS with logical zooming gives the operator an easy overview of the traffic situation without information overloading – by limiting the display to the objects that are relevant at the selected zoom level. The operator should be able to define and save custom views of the GIS visualisation, so each operator receives the information he requires for his tasks. In HCMC, GIS images of flood risk areas may also be combined to provide a more detailed picture of transport risks and opportunities.

**Strategy Management**
Strategy management is a comprehensive system component of traffic control, traffic information, environmental traffic management and incident detection, which should allow system-wide, urban and inter-urban traffic management. All actions of the different subsystems can be coordinated, so their impact can be focused and potential conflicts resolved to maximise the benefit of the road infrastructure. A suitable strategy management reacts on predefined as well as online calculated situations with a series of definable actions. Situation detection with access to all data in the main system (including traffic detection, traffic incidents and any other events) continuously monitors the connected subsystems, traffic and environmental events.

**Flexible, Industry-Standard Interface**
A central interface to the system is crucial for the integration and future extension of the traffic management system. Industry standards such as OCPI allows the convenient integration of other subsystems in the traffic management area. Using industry standards to define protocol and data formats to be used for the exchange of traffic-related data between the central system and other systems can significantly reduce cost over time.

**Secure Remote Service**
A robust remote service platform must be subject to stringent security guidelines. In order to safeguard the data integrity and assure data security, all data should only be sent encrypted over virtual private network tunnels. The operators’ network is best separated from the outside network by a “demilitarised zone”, in order to ensure the highest possible security standards. All access servers are recommended to be designed redundantly for a reliable service access in the case of serious incidents in the city.

**Sub-systems**
While the central traffic management application controls all sub-systems, the sub-systems themselves are the control instance for all field equipment. The sub-system servers are the central endpoints of the sub-system communication network, and monitor as well as operate the outstations. A selection of sub-systems that are recommended for HCMC can been found in the main report.
Based on Arup analysis for this study; assumes no investment in infrastructure is made.

All figures quoted in the text are in 2012 prices and discounted, unless otherwise stated.


The Economist, 2013. Can China clean up fast enough?


Centre for Economics and Business Research Ltd (CEBR/INRIX), 2013. Economic and environmental costs of gridlock.


Future City, Glasgow. Integrated Operations Centre.


Nam, V., The Saigon Times, 2014. HCMC targets 10% GDP growth this year.


The delay to each road journey kilometer in HCMC is around 0.6 minutes, meaning each kilometer takes 0.6 minutes longer than it would under free-flow conditions. HCMC has only a slightly lower delay time than London, at 0.7 minutes per kilometer.


Based on Arup analysis.


Ibid.

Ibid.


As of 30Oct, 2012, 20,000 vehicles are using the ITMS to navigate HCMC’s roads.

Represented the ‘do minimum’ scenario where congestion is forecast to continue rising, assuming no interventions made. Also, extreme weather is forecast to increase from 180 hours in 2015 to 216 hours by 2050. An explanation of assumptions and limitations of the analysis are included in the Appendices.

58 References

1 Based on Arup analysis for this study; assumes no investment in infrastructure is made.
2 All figures quoted in the text are in 2012 prices and discounted, unless otherwise stated.
5 The Economist, 2013. Can China clean up fast enough?
7 Centre for Economics and Business Research Ltd (CEBR/INRIX), 2013. Economic and environmental costs of gridlock.
10 Future City, Glasgow. Integrated Operations Centre.
14 Nam, V., The Saigon Times, 2014. HCMC targets 10% GDP growth this year.
20 The delay to each road journey kilometer in HCMC is around 0.6 minutes, meaning each kilometer takes 0.6 minutes longer than it would under free-flow conditions. HCMC has only a slightly lower delay time than London, at 0.7 minutes per kilometer.
22 Based on Arup analysis.
24 Ibid.
25 Ibid.
30 Represents the ‘do minimum’ scenario where congestion is forecast to continue rising, assuming no interventions made. Also, extreme weather is forecast to increase from 180 hours in 2015 to 216 hours by 2050. An explanation of assumptions and limitations of the analysis are included in the Appendices.
31 Based on Arup analysis.
32 An automated fare collection system will also help to secure predictable revenue flows through the public transport system, and may be integrated as part of the transport management system to provide data on ridership figures and congestion across the public transport network. Our analysis has not accounted for these additional benefits.
33 City Climate Leadership Awards, Buenos Aires: Plan for Sustainable Mobility.
34 Center for Clean Air Policy, 2012. Developing Sustainable Transportation with the Guangzhou Bus Rapid Transit System and Multi Modal Transport Network.
36 All values quoted are in 2012 prices and undiscounted, unless otherwise stated.
37 Based on the costing for a previous ITMS proposal: http://www.roadtraffic-technology.com/news/inho-chi-minh-city-in-vietnam-plans-traffic-control-system. Includes financing costs related to a PFI structure. Arup Analysis was employed to interpolate these costs over the period of study. See technical appendix for further details.
38 The lifetime capital costs of the ITMS are $616 million including renewals costs.
39 Based on Arup analysis.
40 The reductions in emissions and accidents quoted in the table are only attributable to the ITMS system.
41 TfL, 2014. Changes to the Congestion Charge.
42 Calculations resulting from Arup Analysis.
43 Our analysis demonstrates that if the number of registered vehicles increases as forecast to 2045, then fuel consumption will decrease from 5.8 billion litres in 2015 to 3.7 billion in 2045 – assuming an increase in fuel consumption.
46 Millward, S., Tech in Asia, 2014. Reinventing four wheels: 14 apps that are changing the way we get around.
48 Phasing of MRT sections has been assumed to follow the plans set out in Asian Development Bank publications. This study is not intended to provide a robust appraisal of the MRT system, due to the complexity of this work and the scope of this study; instead the analysis focuses on the number of trips generated by the MRT and how this will impact vehicle trips numbers and overall congestion.
50 Based on Arup analysis.
51 Figures from the Asian Development Bank and Arup Analysis based on previous projects in the region.
53 Based on Arup analysis.
54 Based on Arup analysis.
55 A BCR of 1.5:1 is deemed to be the absolute minimum to ensure a project’s viability, with a BCR of 2.0:1 seen as an excellent average figure. These three scenarios are all above this value.